by JOEL POPKIN

The Relationship Between New Orders and Shipments:

An Analysis of the Machinery and Equipment Industries

THE purpose of this article is to examine the relationship between new orders and the shipments which they subsequently generate.[1] It presents an economic model that incorporates a lag between orders and shipments that varies in length over the course of the business cycle. This type of model differs from those based on fixed lags, which have been used more widely in economic analysis. The nature of the variable lag is explained later in the article.

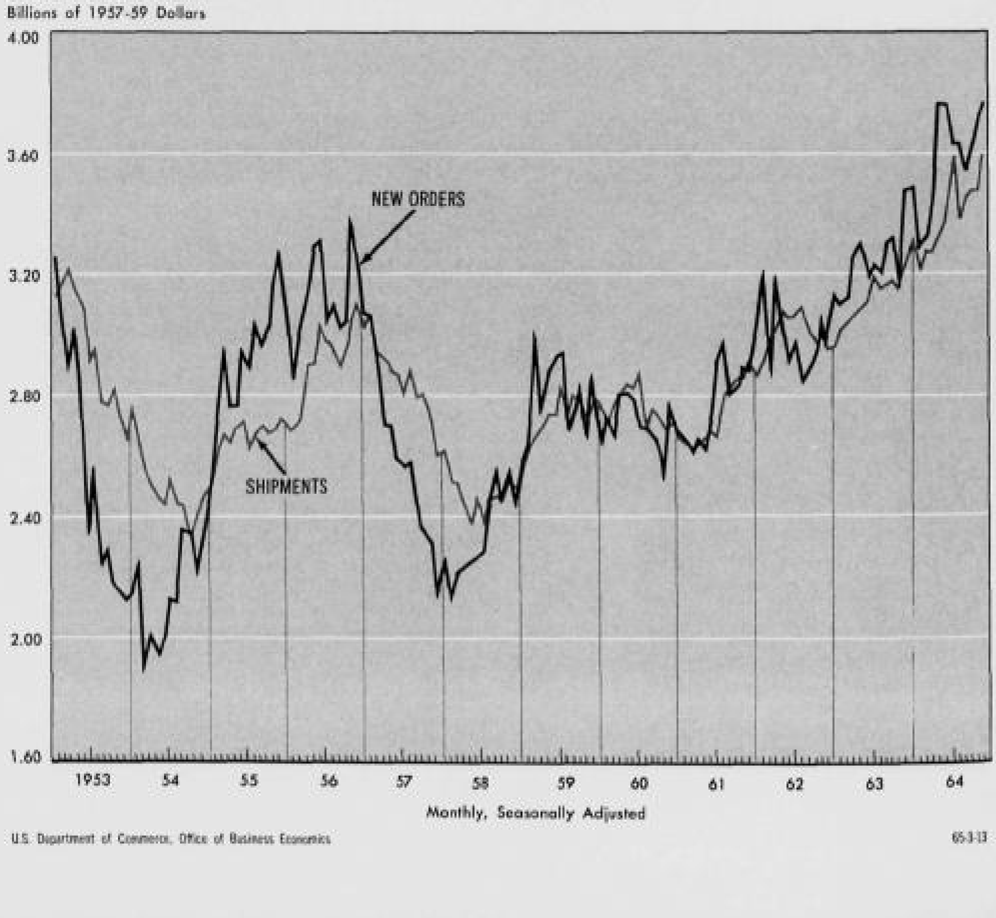
The present study of new orders and shipments is confined to a market classification—machinery and equipment—which cuts across industry lines. The machinery and equipment classification, a category of the new Census Bureau series, comprises certain parts of the electrical and nonelectrical machinery and transportation equipment industries.[2]

Although this article does not deal with fundamental determinants of investment in equipment, an examination of the orders-shipments relationship considered here can help serve another important purpose. That purpose is to provide an explanation of the behavior of producers' durable equipment expenditures, a component of gross national product and a key variable in the prediction of the future course of overall business activity. Once the length of time by which new orders lead shipments has been extablished, the analyst should be better able to judge the time period which must be examined in order to find the factors that influence the placement of orders, such as anticipated profits and sales, and the utilization of capacity. If these factors can be uncovered, it should then be possible to complete the chain from the investment determinants through the new orders link to the actual investment expenditures.

Though estimated separately and by different methods, the producers durable equipment expenditures and the machinery and equipment shipments series overlap substantially. However, the two series differ in coverage in some important respects. Producers' durable equipment includes investment in cars and trucks, a cyclically sensitive expenditure which is not part of the machinery and equipment series. Unlike producers' durables, shipments

CHART 13

New Orders and Shipments of Machinery and Equipment Industries



1. Three other studies to which the reader can usefully refer are: Victor Zarnowitz, "The Timing of Manufacturers' Orders During Business Cycles," *Business Cycle Indicators*, Geoffrey Moore, Editor (Princeton: Princeton University Press, 1961), Vol. I, pages 420–513; Machinery and Allied Products Institute, *Capital Goods Review*, Nos. 35, 42, and 57, August 1958, July 1960, and March 1964; and Walter W. Jacobs and Genevieve B. Wimsatt, "An Approach to Orders Analysis," SURVEY OF CURRENT BUSINESS, December 1949, pages 18–24.

2. Specifically the classification is composed of machinery, except electrical (excluding farm machinery and equipment and machine shops); electrical machinery (excluding household appliances, communication equipment and electronic components); shipbuilding and repairing, and railroads and streetcar equipment. Data from October 1963 onward are published in Bureau of the Census, "Manufacturers' Shipments, Inventories, and Orders." Data for previous months were supplied on request by the Census Bureau.

include exports but exclude imports of machinery and equipment. Despite these differences, the two series have generally moved similarly in the postwar period, so that a link between them should not be difficult to establish.

An examination of the new orders' lead

Monthly seasonally adjusted data on new orders and shipments of machinery and equipment from 1953 through 1964 are found in chart 13. The data have been deflated by the BLS wholesale price index for machinery and equipment since constant dollar series are required later in the analysis. This index differs somewhat in coverage from the orders and shipments series but is the most applicable price index published. From a study of the chart, three observations appear relevant. First, the amplitude of the fluctuations in the new orders series is greater than that in shipments. The mean absolute monthly change in new orders is roughly twice that of shipments. Second, major directional changes in the new orders series occur before those in the shipments series. Third, new orders seem to fluctuate more erratically than shipments.

None of these observations are surprising. When the economy is contracting, decreases in new orders are not fully transmitted to shipments since unfilled orders act as a buffer in providing a basis for shipments. When the economy is expanding, new orders rise more than shipments. This slower advance in shipments may be attributable either to the desire of manufacturers to smooth production or to the limitations of capacity. In either case, unfilled orders again act as a buffer.

The lead of new orders over shipments, observable from the first chart, has varied in length between 4 and 7 months for both peaks and troughs. The new orders series peaked out in January 1953, 4 months before shipments. The exact peak in orders in 1956 is less clearly discernible. It appears to have taken place in June, if the sharp increase in orders in the last 2 months of 1956, due to the Suez crisis, is not considered a peak. On this assumption, shipments reached their peak 6 months later, in December 1956. It is difficult to select the new orders peak in 1960 because of the irregular behavior of the series in 1959, when a major strike occurred in the steel industry. Since many of the effects of the strike were probably worked out by the end of 1959, December of that year could be considered the peak month. Shipments peaked out in July 1960, 7 months later.

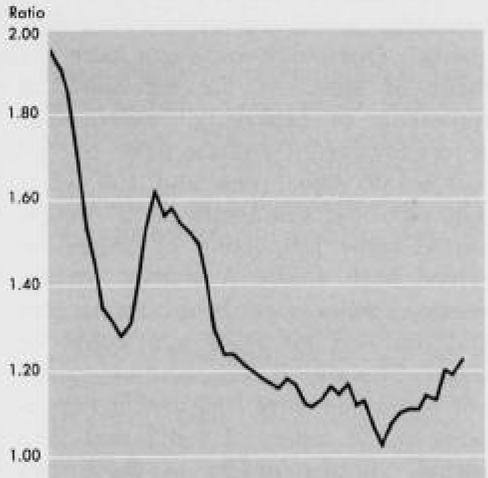
At troughs, the lead of new orders over shipments has diminished. In the 1953–54 recession new orders bottomed out in March 1954, 7 months before shipments. This lead was 5 months in the 1957–58 recession: new orders reached a low in February 1958, shipments in July of the same year. In the 1960–61 recession new orders were at a trough in November 1960 while shipments bottomed out 4 months later.

The leadtimes actually observed can be decomposed into two parts. The first is the actual worktime required to fill an order. Changes in this component of the total lead appear to depend on technological improvements, e.g., faster machines, and therefore should be long run in character. Another factor, difficult to assess without detailed study, which could cause a change in average worktime, would be a shift in the product-mix comprising orders and shipments. The second part of leadtime is that spanning the period between receipt of an order and the start of production on it. This part of the leadtime depends on demand conditions relative to capacity. It tends to be subject to wide cyclical variation but may also change over the long run. When orders are placed at a high rate in relation to capacity or desired levels of operation, backlogs build up. This buildup tends to lengthen the time it takes before work is begun on orders received subsequently. When backlogs fall, work on incoming orders begins more quickly.

The apparent shortening of leadtime at the trough of the cycle suggests the possibility that the actual worktime required to fill an order, one part of the orders' leadtime, may have become shorter due to improved technology or changed product-mix. Such a hypothesis is based on the assumption that at troughs, because of the decline in business activity and new and unfilled orders, leadtimes between receipt of orders and the start of production are short. On this assumption, changes in the actual worktime required to fill an order can be detected with greatest certainty at that phase of the cycle.

CHART 14

Ratio of Unfilled Orders to Shipments of Machinery and Equipment Industries



Quarterly, based on seasonally adjusted 1957-59 dollars

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Unfilled orders-shipments ratio lower

It was noted earlier that unfilled orders act as a buffer between changes in orders and shipments. The extent to which backlogs act as a buffer depends on their size relative to shipments. In chart 14 the ratios of deflated unfilled orders to deflated shipments are presented quarterly from 1953 through 1964.[3] A downward

3. The proper deflation of any stock variable, such as unfilled orders, requires that the various vintages comprising the variable be separated and individually deflated. Since the information needed to make the decomposition of unfilled orders is one of the objects of the study itself, such information was not available beforehand. Therefore, the method of deflation used was to divide unfilled orders by the average value of the BLS wholesale price index for machinery and equipment for the 6 months ending with the date on which each observation on unfilled orders was taken. A 6-month average was used, since the lead of new orders over shipments has rarely exceeded 6 months. Of course, use of the average implies that unfilled orders comprise equal amounts of new orders of the preceding 6 months.

movement is visible in the ratio over the period, particularly in the early years. Three peaks, preceding three business cycle peaks, appear in the series. These are the first quarter of 1953, prior to the 1953–54 recession; the first quarter of 1956, prior to the 1957–58 recession; and the fourth quarter of 1959, prior to the 1960–61 recession.[4] If these peaks in the ratio, together with the last observation (1964–IV), are used to divide the entire period into three subperiods, the decline in the ratio can be studied more closely. Each subperiod roughly encompasses a cycle, so that the ratios for each tend to reflect secular change. Between the first and second peak (1953–I through 1956–I) the average ratio of unfilled orders to shipments was 1.54, that is unfilled orders averaged about one and one-half quarters of quarterly shipments. Between the second and third peak (1956–II through 1959–IV), the average ratio was 1.33, a decline of 14 percent from the preceding subperiod. During the final subperiod (1960–I through 1964–IV) the average ratio fell further to 1.12, a decline of 16 percent from the second subperiod, and 27 percent from the first.

Considered by itself, the decline in the ratio could be interpreted as an indication that the abnormal demand conditions of the Korean War period and the subsequent capital goods boom had ended. Or that productive capacity had risen enough so that work on orders could commence sooner and backlogs could be reduced. (The 1955–57 capital goods boom did add substantially to capacity in most industries.) Thus, the decline in the ratio could reflect solely a reduction in the first part of the orders lead—the time between the placement of an order and the commencement of the work. Certainly part—perhaps the major part—of the decline in the ratio can be attributed to such a reduction. However, the earlier finding that the lag at troughs is shortening does suggest that the worktime required to fill orders, on the average, may have fallen as well.

4. The unfilled orders-shipments ratio may have reached a peak prior to the first quarter of 1953 but data are not available for the period before 1953. However, even if the peak occurred earlier, the conclusions to be drawn about the ratio would not be altered.

A Model Explaining the Orders-Shipments Relationship

THE foregoing analysis can be used to develop a model reflecting the relationship between new orders and shipments. Estimation of the parameters of this model ideally will yield coefficients which can be used to quantify the nature of the relationship. Once this is accomplished, the model may be tested to see how well it forecasts shipments.

In order to understand the structural relationship between orders and shipments and to predict shipments a model is required in which the coefficients can vary. The model should also incorporate coefficients which behave in such a way as to insure that exactly all of the new orders of a time period ultimately are manifested in shipments. The remainder of this article will be devoted to the development and estimation of such a model and to the analysis of the results obtained.

In any time period shipments may be viewed as the weighted sum of the new orders received in past periods. Symbolically this can be stated as

$$\text{(1)} \quad \text{Shipments}_t = \sum_{i=t-1}^{-\infty} \alpha_i \text{ New orders}_i.$$

The α_i's are the weights and represent the percentage of each period's ("i's") new orders which comprise current shipments. Obviously some α_i's have the value of zero. If, for example, all shipments in period "t" represented orders received 4 months prior to "t," α_{t-4} would equal one and the other α_i's, zero. If shipments in "t" represented some proportion of orders received both 4 and 5 months earlier, then α_{t-4} and α_{t-5} would be between zero and one and all other α_i's would be zero. The sum of α_{t-4} and α_{t-5} need not equal one since each coefficient relates to the orders of a different time period. If the orders of those two periods ("$t-4$" and "$t-5$") were very low relative to the manufacturing capacity available to fill the orders, it is possible that the orders of both months could be filled during 1 month. In that case, both α_{t-4} and α_{t-5} would equal one.

If α_{t-4} were 0.5 in the case just discussed, this would be interpreted as meaning that 50 percent of the orders received 4 months earlier were filled in the current month. Assuming that the 50 percent of orders of "$t-4$" filled in "t" were the only orders of "$t-4$" which had been filled, then 50 percent would remain to be filled. Thus, in "$t+1$" the value of α_{t-4} cannot exceed 0.5. Since eventually all of a period's orders must be shipped, the sum of the various coefficients of the orders *of each period* must add to one.[5] An illustrative example of this appears in table 1.

Table 1.—An Example of a Pattern of Shipments Arising from New Orders of 100 Units Placed in Time Period "t"

Time period	Quantity of new orders placed in "t" and shipped in each subsequent period	Proportion ($=\alpha_i$)
$t+1$	0	0.00
$t+2$	0	.00
$t+3$	0	.00
$t+4$	20	.20
$t+5$	35	.35
$t+6$	25	.25
$t+7$	10	.10
$t+8$	5	.05
$t+9$	5	.05
$t+10$	0	.00
Σ	100	1.00

If it could be assumed that each period's new orders were filled in the same pattern as that in table 1, then the prediction of shipments could be obtained by simply solving the following equation:

$$\text{(2)} \quad S_t = 0.20N_{t-4} + 0.35N_{t-5} + 0.25N_{t-6} + 0.10N_{t-7} + 0.05N_{t-8} + 0.05N_{t-9},$$

where S stands for shipments and N, new orders. Obviously, this equation

5. This would not be true if some orders were subsequently canceled. Cancellations are discussed later in the article.

would fail in the real world since the coefficients are not fixed but are constantly changing.[6] Also, some new orders terms which are implicitly in the equation above with zero coefficients, e.g., $0.0N_{t-9}$ and $0.0N_{t-10}$, might enter some calculations of shipments if their coefficients became positive because of the shortening or lengthening of the leadtime required to fill orders.

Six-month or two-quarter lead suggested

The examination of the shipments and orders data at peaks and troughs suggests that orders lead shipments by from 4 through 7 months.[7] This leadtime suggests the equation

$$(3)\qquad S_m=\alpha_1 N_{m-4}+\alpha_2 N_{m-5}+\alpha_3 N_{m-6}+\alpha_4 N_{m-7},$$

where the subscript "m" refers to months. This equation must be modified to permit the coefficients to vary over time and to insure that all of each period's new orders utlimately result in shipments. To achieve these requirements without undue complication of the model and its statistical estimation a simplification is helpful: the monthly data should be aggregated to a quarterly basis to reduce the number of terms in the equation. Therefore, let S_t be defined as a variable measured quarterly and be equal to the sum of shipments of months "m," "$m-1$," and "$m-2$." Similarly, let N_{t-1}, on a quarterly basis, equal the sum of orders of months "$m-3$," "$m-4$," and "$m-5$," and let N_{t-2} equal the sum of orders of months "$m-6$," "$m-7$," and "$m-8$." By aggregating in this manner some precision is lost, but the quarterly data include most of the orders of past monthly periods which seem to influence shipments. The equation can then be rewritten as

$$(4)\qquad S_t=\alpha_1 N_{t-1}+\alpha_2 N_{t-2}.$$

The variable coefficients

The next step is to provide for variation in α_1 and α_2.[8] It will be recalled that variations arise because of changes in the length of time between the receipt of an order and the start of work on it and changes in the amount of production time required to produce an item. Both types of changes appear to be reflected in the ratio of unfilled orders to shipments $\left(\frac{U}{S}\right)$. Thus, the use of this ratio as a variable explaining changes in the coefficients seems to be suggested.

The relationship between $\frac{U}{S}$ and the coefficients should be such as to make α_2 rise relative to α_1, when $\frac{U}{S}$ rises. This is the equivalent of making N_{t-2} more important than N_{t-1} in explaining shipments in "t." In other words, when backlogs rise relative to shipment levels, recently received orders pile up and shipments will tend to consist of orders received in the more distant past. The reverse, of course, is true when unfilled orders fall relative to shipments.

To incorporate this variation into the equation first assume that

$$(5)\qquad \alpha_{1,t}=\beta_0+\beta_1\left(\frac{U}{S}\right)_{t-1}.$$ [9]

Notice that the subscript "t", on α_1, is now needed since α_1 will take on different values in each time period. It is possible to make α_2 depend on $\frac{U}{S}$ in the same way as α_1. However, this would not insure that 100 percent of a period's new orders resulted in shipments. When N_{t-1} becomes N_{t-2}, in period "$t+1$," it will have the coefficient $\alpha_{2,t+1}$. If $\alpha_{1,t}$ and $\alpha_{2,t+1}$ can be constrained to add to one, then 100 percent of each period's orders will result in shipments. Therefore, set $\alpha_{2,t+1}=1-\alpha_{1,t}$. Since $\alpha_{1,t}$ is equal to $\beta_0+\beta_1\left(\frac{U}{S}\right)_{t-1}$, substitute this expression for $\alpha_{1,t}$. This yields

$$\alpha_{2,t+1}=1-\left[\beta_0+\beta_1\left(\frac{U}{S}\right)_{t-1}\right].$$

Then one period earlier,

$$(6)\qquad \alpha_{2,t}=1-\left[\beta_0+\beta_1\left(\frac{U}{S}\right)_{t-2}\right].$$

There now exist expressions for both $\alpha_{1,t}$ and $\alpha_{2,t}$ which can be substituted into the original equation. This yields

$$S_t=\left[\beta_0+\beta_1\left(\frac{U}{S}\right)_{t-1}\right]N_{t-1}+\left(1-\left[\beta_0+\beta_1\left(\frac{U}{S}\right)_{t-2}\right]\right)N_{t-2}.$$

This can be rewritten as

$$S_t=\beta_0 N_{t-1}+\beta_1\left(\frac{U}{S}\right)_{t-1}N_{t-1}+N_{t-2}-\beta_0 N_{t-2}-\beta_1\left(\frac{U}{S}\right)_{t-2}N_{t-2}.$$

Collecting terms yields

$$S_t=\beta_0[N_{t-1}-N_{t-2}]+\beta_1\left[\left(\frac{U}{S}\right)_{t-1}N_{t-1}-\left(\frac{U}{S}\right)_{t-2}N_{t-2}\right]+(1)N_{t-2}.$$

The two terms in brackets are changes between time periods which can be represented by Δ's. Then the final equation to be estimated is

$$(7)\qquad S_t=\alpha_0+\beta_0\Delta N_{t-1}+\beta_1\Delta\left(\frac{U}{S}N\right)_{t-1}+\beta_2 N_{t-2}+u_t.$$

The term α_0 is a constant term included to reflect any systematic departures from the hypothesis. The term ΔN_{t-1} is the difference between new orders of "$t-1$" and "$t-2$". Similarly, $\Delta\left(\frac{U}{S}N\right)_{t-1}$ is the difference between the product of the unfilled orders (end of period)-shipments ratio and new orders for period "$t-1$" and "$t-2$". The development of the model shows a coefficient of one on N_{t-2}. However, a coefficient, β_2, which can differ from one was introduced instead in order to reflect

6. An equation, based on quarterly data, incorporating fixed coefficients was estimated. The results obtained were not as good as those based on the variable coefficient model. These latter results are found in equation (8) below.

7. This is not to say that orders for some types of machinery—power-plant generators, or welding apparatus, perhaps—may not take more than 7 or less than 4 months to fill. Rather, the leadtime uncovered is the average time consumed from the placement of orders to shipments of all types of machinery and equipment.

8. An application of a variable coefficient model can be found in Edward Greenberg, "A Stock Adjustment Investment Model," *Econometrica*, Vol. 32, No. 3 (July 1964), pages 339–357. Mr. Greenberg's model incorporates one variable coefficient which is made to depend on several relevant variables. In this article a model is developed which incorporates two such coefficients with an assumed interrelationship.

9. Other relationships between α_1 and $\frac{U}{S}$ could have been specified. The linear relationship used here seems to be reasonable and was convenient to use. The constant term was inserted to permit the reflection of any departures from strict proportionality between α_1 and $\frac{U}{S}$.

possible departures from the underlying theory which cannot be assumed to hold rigorously.[10] The u_t are random disturbances introduced because in the real world the equation cannot be expected to hold exactly in all time periods.

The equation was fitted to the 45 quarterly observations from the third quarter of 1953 through the third quarter of 1964. The shipments and new orders variables, measured in billions of 1957–59 dollars, were derived by deflating each month's observation by its respective deflator (the BLS wholesale price index for machinery and equipment) and summing over each calendar quarter. The unfilled orders variable was obtained by deflating the end of period stock of unfilled orders by the average of the price index for the preceding 6 months. This was done to account for the fact that, under current assumptions, unfilled orders can comprise up to 6 months of new orders.

Results

The estimation of the equation, using the ordinary least squares method, yielded the following results:

$$(8)\quad S_t=\underset{(6.29)}{2.409}+\underset{(5.16)}{1.035}\Delta N_{t-1}-\underset{(3.70)}{0.390}\Delta\left(\frac{U}{S}N\right)_{t-1}+\underset{(16.09)}{0.717}N_{t-2}.$$

The numbers shown in parentheses are the ratios of the regression coefficient to their standard errors ("t" ratios). The ratios indicate that all the estimated coefficients are significant at the 1 percent level. The coefficient of determination, $(\bar{R}^2)$, the ratio of the explained variance in the dependent variable to the total variance in the dependent variable, adjusted for degrees of freedom, is 0.868, significant at the 1 percent level. The adjusted standard error of estimate $(\overline{SEE})$ is \$0.271 billion which indicates that about 95 percent of the observations during the sample period lie within \$0.542 billion (two standard errors) of the computed regression line. (The mean value of shipments during the period is \$8.46 billion.) The serial correlation coefficient (SCC), measuring autocorrelation in the residuals, is 1.292, significant unfortunately at the 1 percent level.

It will be recalled that the variable coefficients on the two lagged new orders terms were imbedded in the initial equation. These coefficients can be obtained as follows:

$$S_t=2.409+1.035\Delta N_{t-1}-0.390\Delta\left(\frac{U}{S}N\right)_{t-1}+0.717N_{t-2};$$

$$S_t=2.409+1.035N_{t-1}-1.035N_{t-2}-0.390\left(\frac{U}{S}\right)_{t-1}N_{t-1}+0.390\left(\frac{U}{S}\right)_{t-2}N_{t-2}+0.717N_{t-2};$$

$$S_t=2.409+1.035N_{t-1}-0.390\left(\frac{U}{S}\right)_{t-1}N_{t-1}-1.035N_{t-2}+0.717N_{t-2}+0.390\left(\frac{U}{S}\right)_{t-2}N_{t-2};$$

(9)

$$S_t=2.409+\left[1.035-0.390\left(\frac{U}{S}\right)_{t-1}\right]N_{t-1}+\left[-0.318+0.390\left(\frac{U}{S}\right)_{t-2}\right]N_{t-2}.$$

The terms in brackets in the last equation are estimates of α_1 and α_2, respectively. In chart 15 each of the estimates is plotted against $\frac{U}{S}$. It can be seen that α_1 varies inversely with $\frac{U}{S}$. This implies that the greater the backlog of orders relative to shipments, the smaller the amount of new orders of "$t-1$" which will be filled in "t". It can also be seen that α_2 varies directly with $\frac{U}{S}$. This indicates that a high ratio of $\frac{U}{S}$ results in an increase in the proportion of shipments in "t" attributable to new orders in "$t-2$." This is understandable since the high $\frac{U}{S}$ resulted in the filling of a small part of the new orders of "$t-2$" during the preceding period—"$t-1$." The combined effect of the two coefficients is to lengthen the lead of new orders over shipments when the backlog of unfilled orders is high, and to reduce the lead when unfilled orders fall relative to shipments.

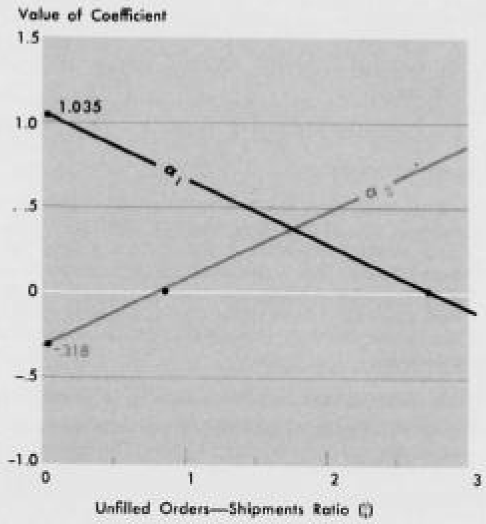
In addition the coefficients $\alpha_{1,t}$ and $\alpha_{2,t+1}$ always add to a fixed constant. This constant is 0.717, not the 1.0 originally specified. This is due to the fact that the constant term in the regression equation adds \$2.409 billion. The ratio of the constant term to average new orders of "$t-2$" during the sample period is 0.289, which, when added to 0.717, totals approximately 1.00. Thus, while the introduction of a constant term somewhat modifies the underlying theory, both the constant and the computed coefficient on N_{t-2} together meet the original assumptions for the period as a whole.[11]

In chart 16 actual shipments and the computed values obtained from use of the equation (8) are presented. The "fit" of the computed to the actual values is quite good, as could have been expected from the interpretation of the various statistics of the estimated equation. However, closer examination of the chart reveals that the

CHART 15

How the Variable Coefficients Change With Unfilled Orders-Shipments Ratio ($\frac{U}{S}$) for Machinery and Equipment Industries

As $\frac{U}{S}$ increases, α_1 decreases and α_2 increases



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10. An alternative equation which could have been presented is $S_t-N_{t-2}=\alpha_0+\beta_1\Delta N_{t-1}+\beta_1\Delta\left(\frac{U}{S}N\right)_{t-1}+u_t$. By bringing N_{t-2} to the left-hand side of the equation, its coefficient is constrained to equal one. Under this circumstance the estimate of the constant term α_0 should be zero. Actually this equation was estimated and α_0 turned out to be small and not significantly different from zero. However the equation did not fit the actual data quite as well as the equation in which N_{t-2} appears on the right-hand side with an unconstrained coefficient. An analysis of the constant term and coefficient of N_{t-2} obtained from fitting this equation is contained in the next section on results.

11. That the estimates of α_0 and β_2 yield results, for the period as a whole, which are equivalent to a coefficient of one on N_{t-2} may be seen below, where $\bar{N}_{t-2}$ is the mean value of the variable during the sample period:

$$\alpha_0+\beta_2\bar{N}_{t-2}=(?)\bar{N}_{t-2};\ 2.409+0.717\bar{N}_{t-2}=(?)\bar{N}_{t-2};$$

$$\frac{2.409}{\bar{N}_{t-2}}+0.717\frac{\bar{N}_{t-2}}{\bar{N}_{t-2}}=(?);$$

$$0.289+0.717=1.006$$

equation misses turning points. Actual shipments change direction one quarter before computed shipments, except at the trough of the 1953–54 recession when computed shipments turn up 3 months before actual shipments. Of course, because the equation fits the data so well, the difference between the computed and actual values of shipments is quite small even in quarters during which the series have moved in opposite directions. In the fourth quarter of 1956, for example, the difference between the two values is only $37 million, despite the fact that actual shipments were rising and computed shipments were falling. Similar situations are apparent in the third quarter of 1957 and the second quarter of 1961.

Modifications of the model

It is difficult to assess the estimated equation. The fit of the equation is good but, at the same time, the equation does not reflect turning points. The turning point difficulty does limit the use of the equation although the good fit still permits forecasts to be made if predicted turning points are carefully interpreted. Even if the equation is not considered suitable for forecasting, it does not follow that it is not useful for studying the orders-shipments relationship since it does explain an extremely large percentage of the overall variation in shipments. Nevertheless, further tests are in order to determine if a better equation can be developed.

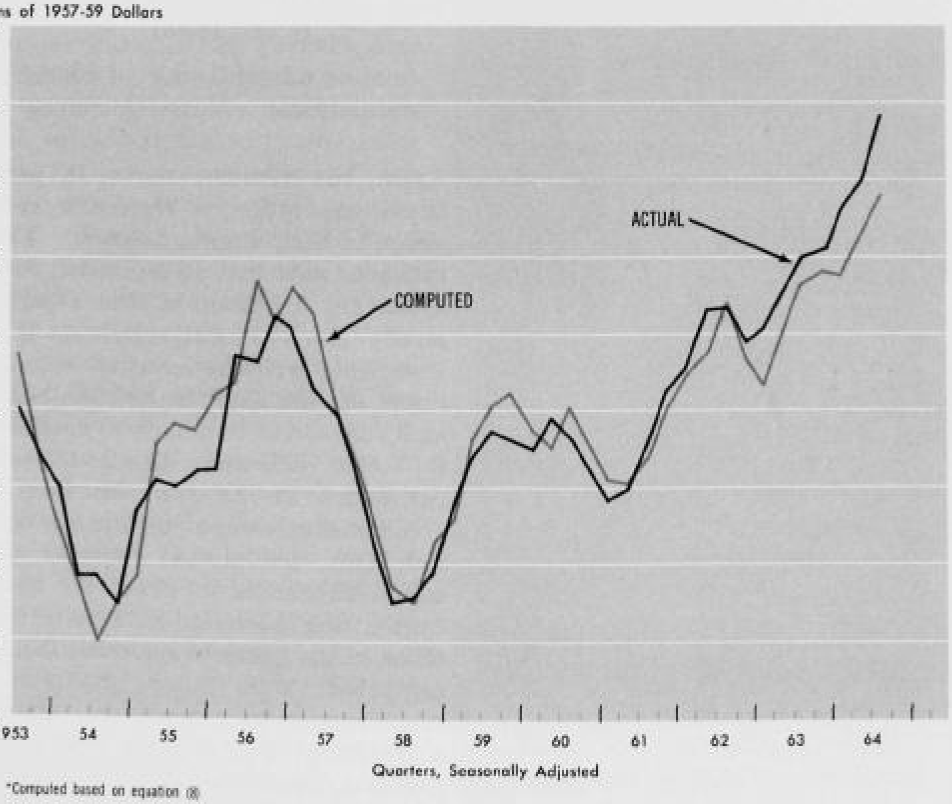
There are several reasons why both the model and the data on which the estimated equation is based may fail to depict fully the relationship between orders and shipments. The specification of the model has four possible shortcomings. First, the variable coefficients in the model were not constrained to prevent computed shipments from exceeding the shipment capacity of machinery and equipment producers. However, the omission of a capacity constraint apparently affected the results only around the 1956 shipments peak. If it is assumed that the $9.1 billion of shipments in the fourth quarter of 1956 called for output at virtually full capacity, then the computed values for the third quarter of 1956 and the first quarter of 1957 exceeded capacity.[12] If a constraint were imposed, the two peaks in shipments, in effect, would have been flattened out along the capacity ceiling. This would have served to defer the downturn even more than one quarter since computed shipments would be forced to edge up along the capacity ceiling until the new orders accumulated because of the capacity constraint were worked off. In no other time period do computed shipments exceed what could be inferred as the capacity of the machinery and equipment producers.[13] Thus, the omission of capacity constraints in this aggregative model should not bias the results very much.

The second shortcoming of the structural model is that it fails to take into account the level of finished goods inventories (for which data are not available) and their use in filling shipments. Greater- or less-than-normal reliance on inventories to meet new orders will result in a shortening or lengthening of the lag between orders or shipments. However, since changes in the lag due to any factor are reflected in the ratio of unfilled orders to shipments, it can be argued that the effects of accumulations and liquidations of finished goods inventories are implicitly accounted for. Also, there is not much production for stock in the machinery and equipment industries. Thus, the failure to treat inventories explicitly does not seem to be an important shortcoming of the model.

The third shortcoming of the model relates to its inability to adjust for severe raw materials shortages—actual or anticipated—such as those associated with strikes. The model continually translates orders into shipments. Some materials shortages which are not severe enough to change the basic lag structure

CHART 16

Shipments of Machinery and Equipment Industries—Actual and Computed *



*Computed based on equation (8)

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12. It is assumed that any increase in capacity from the fourth quarter of 1956 to the first quarter of 1957 was insufficient to satisfy the level of shipments computed for the latter quarter, but this assumption is not necessary for the point to hold.

13. Even though computed shipments exceeded actual shipments at the peak in 1959–60, computed shipments were still below the peak actual shipments in the fourth quarter of 1956.

are accounted for by $\frac{U}{S}$. However, a prolonged strike in an industry such as steel, for example, can result in lengthening the orders lead to three, rather than two quarters and in sharply reducing shipments during the actual strike. The model would not sense such an occurrence and therefore its effect would not be felt on computed shipments. Computed shipments rose in the third quarter of 1956, while actual shipments edged down, probably because of the 5-week strike in the steel industry in July and August of that year. Computed shipments rose in the fourth quarter of 1959, while actual shipments declined. Again, the steel strike which extended from roughly mid-July to mid-November, was probably behind this contraction in actual shipments. These instances suggest that the impacts of strikes or other "shocks" on the economy should be incorporated in the model.[14] Certainly, a forecaster making use of the equation would judgmentally correct predicted values for an event such as a strike.

14. Some readers may be familiar with the use of "dummy" variables in regressions to account for irregular behavior. In the case of strikes, such variables could be used to reflect unusually large increases in orders in anticipation of a strike, and the shock imposed on the economy when either a strike occurs or an expected strike does not materialize.

The fourth shortcoming is the possibility that the lag structure was improperly specified. It will be recalled that chart 13 seemed to indicate that new orders led shipments by from 4 through 7 months. However, turning points in the monthly orders and shipments series were difficult to pin down specifically because of the presence of random movements in both series. In addition, the use of calendar quarter aggregates introduces some lack of precision, as recognized earlier, even though most of the relevant monthly shipments figures are included in the two, lagged, new orders variables.

Because actual shipments frequently lead computed shipments at turning points, it may well be that the lag structure of the model was somewhat improperly specified. In the development of the model estimated above the months of new orders included were those of "$m-3$," "$m-4$," and "$m-5$" (in the term N_{t-1}), and "$m-6$," "$m-7$," and "$m-8$" (in the term N_{t-2}). When the variable coefficients are equal so that N_{t-1} and N_{t-2} are weighted equally the average implicit lag is 4.5 months. Suppose the "true" average lag was actually one month longer or shorter than that used. Then it would be appropriate to sum new orders into two quarterly variables covering "$m-4$" through "$m-9$" to lengthen the lag, or covering "$m-2$" through "$m-7$" to shorten it.

Both possibilities were tested and the shortening of the lag by one month yielded better results than lengthening it. When the lag is shortened some overlapping occurs. New orders of quarter "$t-1$" include those of month "$m-3$" and shipments of quarter "t" include those of month "$m-3$." There is nothing inherently wrong in this lag structure. The measure of its validity is the degree to which the results it produces conform with the real world.

The equation (10) below was estimated incorporating the new, shortened lag structure. In this equation the subscript "t" refers to calendar quarters and the subscript "s" to quarters composed of the last 2 months of one calendar quarter and the first month of the next. The equation is

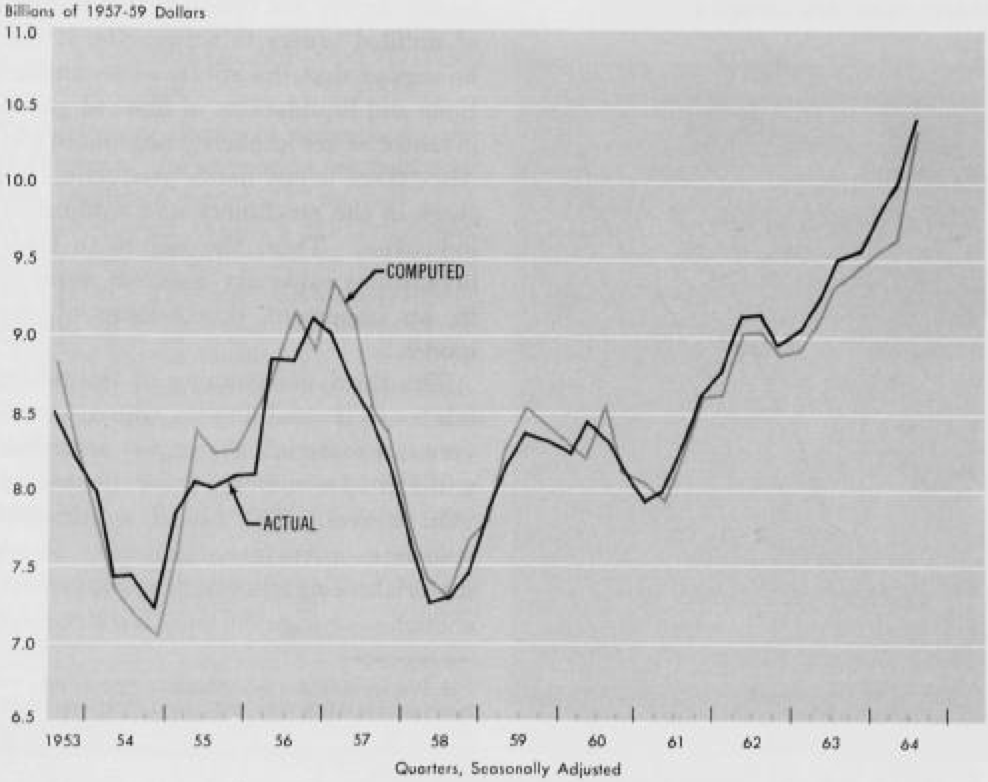
$$(10)\quad S_t = \underset{(4.24)}{1.456} + \underset{(8.73)}{1.045}\Delta N_{s-1} - \underset{(7.46)}{0.642}\Delta\left(\frac{U}{S}N\right)_{s-2} + \underset{(20.76)}{0.825}N_{s-2}.$$

Again, the numbers shown in parentheses are ratios of regression coefficients to their standard errors. These ratios indicate that all regression coefficients are significant at the 1 percent level. The $\bar{R}^2$ is 0.921, significant at the 1 percent level; the adjusted standard error of estimate is \$0.209 billion, and the serial correlation coefficient is 1.573, indicating significant serial correlation at the 5 percent level.

Shipments, computed from the equation (10), are plotted together with actual shipments in chart 17. Aside from fitting the actual data better than those of the previous equation (8), the computed values change direction simultaneously with the actual values in a greater number of cases than in the previous equation. Unlike equation

CHART 17

Shipments of Machinery and Equipment Industries—Actual and Computed*



* Computed based on equation (10)

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(8), directional changes in the actual values and values computed from equation (10) coincide in 1955–I, 1955–III, 1955–IV, 1959–IV, 1963–I, and 1964–I. In all, the new equation (10) yields results which coincide with actual movements in 7 of the 13 turning points in the shipments series. However, while the second equation (10) seems to provide a better forecasting framework it is not possible to infer unequivocally that its lag better reflects the nature of the relationship between orders and shipments.

Impact of canceled orders

Apart from the foregoing shortcomings which relate directly to the specification of the model there are other factors which might explain some of the departures of computed from actual values. One of these is the lack of information on the cancellation of orders. The new orders series is calculated net of cancellations, since it is computed by adding the change in unfilled orders to shipments.[15] Thus, if a cancellation out of the preceding months' orders occurs during the current month, new orders of the current, not the preceding month, will reflect the cancellation. If cancellations were the same amount from month to month no error would be introduced into the model through the new orders data. Each period's new orders would be lower by the amount of the preceding period's cancellations charged to it, but higher by the same amount because cancellation of the current period's orders would not be reflected. Assume that this had been the case during the expansion phase of a cycle. Assume further that in the first quarter of contraction there was an increase in the cancellation of orders which had been placed in the last two quarters of the expansion. Thus, these latter two quarters of orders would be overstated while orders in the first quarter of contraction would be understated. The model would translate the overstated orders of the last two quarters of expansion into shipments during the first quarter of contraction. Thus, shipments would be too high in the first quarter of contraction. This might explain why the model results do not turn down when actual shipments do. The same logic can also be used to explain a lag at the trough, particularly if the contraction phase is short. While failure to account for canceled orders seems to be a plausible explanation of missed turning points, there is no readily available remedy for this deficiency in the data.

Calendar versus noncalendar aggregates

Another possible shortcoming of the model is the way in which the quarters were combined from the monthly data. The variables were based on calendar quarters, i.e., January–March, etc. As alternatives, three-month totals could have been built up by starting with February or March. Data were compiled using one of these alternatives—beginning with February. Thus, for each variable, the four quarterly observations are February–April, May–July, August–October, and November–January. These data, used to re-estimate the original model (7), yielded the following results:

$$(11)\quad S_s = \underset{(3.98)}{1.695} + \underset{(6.50)}{0.966}\Delta N_{s-1} - \underset{(4.68)}{0.500}\Delta\left(\frac{U}{S}N\right)_{s-1} + \underset{(16.23)}{0.800}N_{s-2}$$

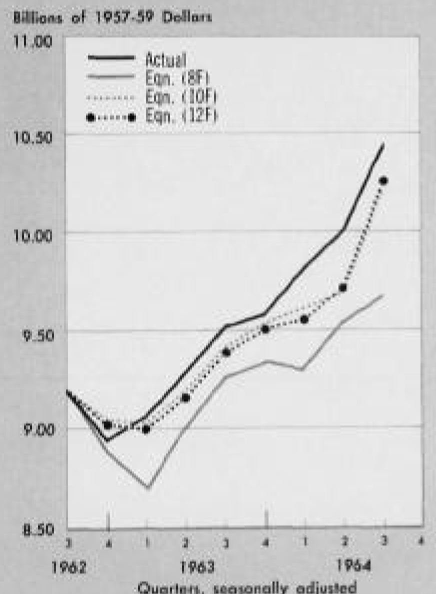
where the subscript "*s*" denotes quarterly aggregates based on a different time period, i.e., February–April, etc. Equation (11) is slightly better than equation (8): the $\overline{R}^2$ is 0.887 as compared with 0.868 in the first equation. The adjusted standard error of estimate is $0.260 billion versus $0.271 billion for the first equation. The most notable improvement is in the serial correlation coefficient, which is 1.568, still significant but only at the 5 percent level; the coefficient of serial correlation was significant at the 1 percent level in the first equation. As in equation (8) all regression coefficients and the constant term are highly significant. Directional changes in shipments computed from equation (11) coincide with actual changes in two more instances than in equation (8), but a large number of changes remain unaccounted for.

On balance, the difference between the two equations seems minor. The small difference between the two seems to suggest the obvious point that some precision is lost in capturing a lag structure when the time over which each observation is measured is lengthened. However, the loss in this case seems small enough to be overlooked, in view of the simplicity with which the variable coefficient model could be developed by using two quarterly lag terms rather than four or more monthly lags.

CHART 18

How the Equations Forecast Shipments of Machinery and Equipment Industries

• *Modifications improve forecasts*



Note.—Equations on which forecasts are based appear in footnote 18.

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Price deflation problems

Another factor which could possibly have contributed to the difference between actual and computed values of shipments is the method of deflating the orders and shipments variables. Both series were deflated by the value of the index at the time period each occurred. This assumes that orders are placed at prevailing prices but that these prices may be changed when the orders are shipped. But it is also

15. *Manufacturers' Shipments, Inventories, and Orders: 1947-63* (Revised), page 13, Bureau of the Census, U.S. Department of Commerce, Washington, D.C. The new orders series is derived from seasonally unadjusted data. After each series is independently seasonally adjusted new orders no longer need equal shipments plus the change in unfilled orders. The difference is usually small.

possible that price changes are first put into effect at the ordering stage and that the price at which the order is placed prevails at the time of shipment. If this is the case, then the portion of orders of "t−1" and "t−2" which will be shipped in "t" should have been deflated by the index for "t."[16] Failure to do so, in a period of rising prices, results in an overestimation of the physical volume of orders, causing an overestimation of the physical volume of shipments. If prices have risen, but at a uniform rate, then the upward bias in shipments will be constant over time and will be reflected in the constant term of the equation. If the rate of price change varies (as, of course, it has) then the constant term will not reflect greater- or less-than-normal price changes and the resulting estimates will suffer.

To correct for this possible defect an additional variable was introduced: the change in the wholesale price index for machinery and equipment over the preceding two quarters ($WPI_t - WPI_{t-2}$).[17] This variable substantially improved all three equations which have been presented. The equation which yielded the best fit after introduction of the price variable was the one with the shorter lag structure (10). This equation gave the best fit of all three equations (8, 10, 11) before the price variable was introduced. The new equation is

$$(12)\quad S_t = \underset{(4.92)}{1.475} + \underset{(3.73)}{0.943}\Delta N_{t-1} - \underset{(7.53)}{0.579}\Delta\left(\frac{U}{S}N\right)_{t-1} + \underset{(24.00)}{0.835}N_{t-2} - \underset{(3.72)}{8.01}(WPI_t - WPI_{t-2})$$

The $\bar{R}^2$ is 0.940 and the adjusted standard error of estimate is $0.183 billion. The introduction of the variable served to eliminate virtually all serial correlation (serial correlation coefficient = 1.965), the presence of which may reflect the omission of a variable. The minus sign on the price variable conforms with expectations. It serves to reduce shipments (when prices are rising) to compensate for the overstatement of orders resulting from the use of a deflator which is too low. The statistical significance of the regression coefficient on the price change variable is an indication that in an important number of cases price increases are applied to incoming orders and shipments are made at the price reflected in the orders.

While the fit of the equation is improved, the equation performs slightly less well at turning points than it did without the price change variable. Furthermore, the introduction of the price change variable prevents the use of the equation for forecasting purposes unless an independent estimate of WPI_t is made.

Thus far, four equations (8, 10, 11, and 12) have been presented and analyzed. A further test of each equation, relating to its ability to forecast shipments, can be performed. This test is to omit observations for the more recent period, to reestimate each equation for the now shorter period, and to forecast the omitted period with each of the equations. These forecast shipments can then be compared to the actual shipments for each equation to see which performs best. The results of this experiment, omitting the last eight quarterly observations, for the three equations in which the dependent variable is shipments on a calendar quarter appear in chart 18.[18] The constant term of each equation was adjusted so that the shipments' values computed by the equations would coincide with actual shipments in the third quarter of 1962, the "jump-off" quarter for the forecasts. Equation (8F) is the estimate of the original model; equation (10F), the model with the lag shortened by 1 month; and equation (12F), with the shortened lag and the price change variable.[19] This last equation, which was the best equation when all 45 observations were included, gives the best forecast of the 1962–IV—1964–III period. All three forecasts show a decline in 1963–I. Since actual shipments fell in 1962–IV, the decline in predicted values in the subsequent quarter reflects the tendency of all equations to lag one quarter in responding to directional changes. However, for equations (10F) and (12F) the further decline computed for 1963–I is quite small, amounting to $9 million and $28 million, respectively.

16. This would not have been possible since only after the equation was estimated could the portions of orders of "t−1" and "t−2" have been determined. Thus, while the latter method seems preferable, it could not have been applied initially.

17. Also tried, but with less success, was $WPI_t - WPI_{t-1}$. Since N_{t-1} appears in the equation the inclusion of $WPI_t - WPI_{t-1}$ is more logical.

18. The three equations whose forecasts of 1962–IV—1964–III are plotted in chart 18 follow:

$$(8F)\quad S_t = \underset{(9.64)}{3.404} + \underset{(5.15)}{0.842}\Delta N_{t-1} - \underset{(4.32)}{0.356}\Delta\left(\frac{U}{S}N\right)_{t-1} + \underset{(13.65)}{0.586}N_{t-1},$$
$$\bar{R}^2 = 0.846,\ \overline{SEE} = 0.211,\ SCC = 1.664$$

$$(10F)\quad S_t = \underset{(5.83)}{2.436} + \underset{(6.08)}{0.811}\Delta N_{t-1} - \underset{(5.70)}{0.516}\Delta\left(\frac{U}{S}N\right)_{t-1} + \underset{(14.07)}{0.702}N_{t-1},$$
$$\bar{R}^2 = 0.875,\ \overline{SEE} = 0.190,\ SCC = 1.80$$

$$(12F)\quad S_t = \underset{(5.18)}{2.185} + \underset{(6.30)}{0.814}\Delta N_{t-1} - \underset{(6.80)}{0.513}\Delta\left(\frac{U}{S}N\right)_{t-1} + \underset{(14.28)}{0.741}N_{t-1} - \underset{(1.96)}{4.978}(WPI_t - WPI_{t-2}),\ \bar{R}^2 = 0.895,$$
$$\overline{SEE} = 0.182,\ SCC = 1.698.$$

19. These numbers coincide with those placed to the left of the equations in the text above estimated from observations for the full period. The "F" indicates they are based only on 37 observations and are used to generate forecasts for the remaining eight quarters for which data were available.